The impact of deep vertical supply chain relationships upon focal-firm innovation performance

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Abstract

Managers increasingly invest in relationships with suppliers and customers to stimulate innovation. Existing literature has demonstrated the potential for diminishing returns to the breadth of relationships but less attention has been paid to the depth of relationships. We combine resource based theory with social capital perspectives to consider the depth of vertical inter-firm relationships and their impact on innovation for a focal firm. Using multivariate analysis to examine supplier-led and user-led innovation across firms in UK manufacturing, we find that embedded relationships in either direction correlate with both product and/or process innovation. However, with further depth of embeddedness, simultaneous and varied effects on product and process innovations occur. Our findings suggest that managers need to understand the unique dynamics of relationship depth (in addition to breadth) upon product and process innovation otherwise the focal firm may waste managerial effort and resources in relationship building.

Keywords: Innovation, Co-operative ties, Strong ties, Increasing and Negative Returns, Manufacturing

JEL Codes: L14, L17, L60, O31

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1. Introduction

The concept of 'openness' has become an important aspect of innovation management strategy. A company's established vertical chain, is a long recognised source of open innovation (see Dahlander and Gann (2010)) and policymakers across the OECD, actively encourage such practices (Bougrain & Haudeville, 2002; DIUS, 2008).

Two dimensions of openness have been identified by Laursen & Salter, (2006): *i) breadth,* ((the number of partners and the scope of their combined activities) and *ii) depth,* (the level of engagement with each partner or quality of the individual inter-firm relationship (Cuevas-Rodríguez et al., 2014)). Many prior studies focus upon breadth and found a positive correlation between inter-firm co-operation and innovation (Dyer & Singh, 1998; Gulati, 1999) although others found diminishing returns may exist (Laursen & Salter, 2006; Leiponen & Helfat, 2010; Love et al., 2014). With respect to relationship depth, rich established ties within a firm (e.g. Aalbers et al. (2014)) can become 'over-embedded', fraught with tensions, and burdened with mutual obligations or closed to new ideas (Christensen & Bower, 1996; Granovetter, 1973; 1985; McFayden & Cannella, 2004; Uzzi, 1997). A similar gloomy side to embeddedness in dyadic relationships in the inter-firm setting also exists (Gulati, 1995; Hagedoorn & Frankort, 2008; Molina-Morales & Martinez-Fernandez, 2006; 2009; 2011; Mowery et al., 1996; Rosetti & Choi, 2005; Saxton, 1997; Uzzi, 1996).

In this paper, we explore the concept of relationship depth and potential over-embeddedness in the context of product and process innovation. We use survey data on supply chain dyads that captures both the depth of inter-firm collaboration and the range of innovative activities in five established UK industries (aerospace, ceramics, information technology, medical equipment and textiles). Uniquely our data captures high levels of refinement by identifying separately both the upstream and downstream dyadic relationship for our focal firms with their *i) main buyer* and *ii) main supplier and their association with product and* *process innovations separately.* Since such dyadic relations involve significant investment in building and sustaining business relations, part of our objective is to understand when, and within which relationship (upstream or downstream), further investment into an existing relationship is likely to be significantly correlated with further innovation, thereby assisting resource allocation decisions.

We adopt the following structure: first, we present our theoretical foundations, exploring the link between cooperation, relationship depth and innovation. We then describe our research design, data and specify our model. This is followed by analysis of the results, a discussion of our research contribution and implications for managers (and policy-makers). Finally, we briefly consider limitations and further avenues for investigation.

2. Theoretical foundations

2.1The resource/capabilities based view (RBV)

Viewing firms as bundles of differentiated resources and specialised capabilities (Langlois & Robertson, 1995; Teece et al., 1990), allows focal firms to develop supply chains for strategic outsourcing with partners who have similar, but differentiated resources/capabilities which may lead to innovation (Hakansson, 1987; Richardson, 1972; Von Hippel, 1976; 1988). The firm's absorptive capacity enables it to combine and exchange knowledge resources through the supply chain and this is strongly associated with a firm's innovative capability (Kogut & Zander, 1992).

On the upstream supply side, Lakshman and Parente (2008) found that 'supplier-focused knowledge management' had a significant, positive impact in delivering higher levels of product performance in the focal firm, while Cousins et al. (2011) have shown that proactive engagement in 'supplier technical exchange' enhances firms' capabilities and improves product development. However, this is mitigated by the degree of similarity in the resources/capabilities of the firms. Firms who are too similar will be less innovative because the resource/capability differential needs to be large enough to generate a knowledge gap which might present an opportunity for innovation. However, this gap must be bridgeable by the respective firms' absorptive capacities for them to engage in meaningful knowledge exchanges (Cepeda-Carrion et al., 2012; Cohen & Levinthal, 1989; 1990). If the gap is too large, the firms are unable to understand each other and identify the potential for innovation between them (Phene et al., 2006). Thus increasingly differentiated resources could potentially lead to improved, more rapid and more frequent innovation initially, but past some point, the growing distance could have a negative impact; an inverse-U shape emerges suggesting an optimal level of differentiation exists. Additionally, the complementarity between resources by 'locking in' downstream clients into relationship-specific investments enables suppliers to safeguard and appropriate value from the relationship (see Katz (1986); Subramani (2004)) and such actions may harm innovative endeavour further downstream (Torugsa & Arundel, 2013; Zsidisin et al., 2005).

On the downstream side specifically, innovative opportunities often arise in knowledge transfer and the exchange of technical information between focal-firm and users (Tether, 2002; von Hippel, 1988). The RBV might suggest that user interaction would allow the focal-firm to exploit its existing resources by making incremental innovations to existing products in response to users' demands. Franke and Piller (2004) and Franke et al. (2006) have investigated how customer knowledge and capabilities can impact new product designs. Customers are now sources of new product and service ideas and innovations in several industries (Greer & Lei, 2012). Thus the deepening of relationships with existing customers may have positive impacts upon innovation, particularly if lead-users are among the existing customer base. However, Christensen (1997) and Christensen and Bower (1996) have argued that in focusing too much upon existing users, the focal-firm may risk missing out on new opportunities in more radical innovations. Countering this view, Zander and Zander (2005) have suggested that on-going deep relationships with existing customers might in fact also lead to the exploration and generation of new resources by the focal firm, not just exploitation of existing ones. The impact of deep relationships with existing customers is therefore unclear.

2.2 Innovation within conditions of relational embeddedness

2.2.2 Support for a positive relationship

Whilst access to external resources and capabilities may lead to greater innovation by a focal firm, market-based transactions can be riddled with opportunism and appropriability (Williamson, 1985). Co-operative ties may act as an alternative governance mechanism through the promotion of social norms and informal codes of conduct among partner firms (Aldrich & Fiol, 1994; Bozdogan et al., 1998; Dyer & Singh, 1998; Granovetter, 1992; Jessop, 1998; Parkhe, 1993; Uzzi, 1997). Social capital and trust may strengthen resource-based relationships as partner firms are more likely to engage in resource pooling, joint technological development and collectively improving the appropriability of innovations along the value chain (Harabi, 1998; Negassi, 2004). Critical sourcing supply-based relationships are of vital strategic importance for manufacturing firms and require investments of time, effort and resources (Cousins and Lawson (2007)). Also, long term orientation (which is reflected partly by relationship depth) has also been found to forestall opportunism between suppliers and buyers (Lui & Ngo, 2012).

In upstream relationships, Kotabe et al. (2003) found the duration of US and Japanese auto supply chain relations to be positively associated with high level technology transfers, while Henke and Zhang (2010) claim collaboration with suppliers can build trust, reduce relational stress and increase innovative activities. Tomlinson (2010) reports a significant positive association between the degree of co-operation and innovation over a range of supply chain activities within UK manufacturing. In downstream relationships, (Squire et al., 2009) found higher levels of buyer-supplier co-operation were positively correlated with levels of knowledge transfer between firms. Tsai et al. (2013) demonstrate that buyer–seller social capital indirectly affects innovation performance via the mediation of commitment to innovation and customer knowledge development. Finally, Kühne and Gellynck (2013) found that trust and social satisfaction enhanced relationship quality along the entire supplier-manufacturer-customer chain in the food industry and that relationship quality in turn, enhanced innovation capacity and innovative activities.

Indeed, the source of the external stimuli may affect product and process innovation to differing degrees (Pavitt, 1984, 1990). Freel and Harrison (2006)'s study found that in UK manufacturing, 'novel' product innovators were more likely to engage in co-operation with buyer firms than 'non-innovators', while in process innovation, supplier co-operation was significantly associated with 'novel' process innovations. From a strategic management perspective, it matters (for the allocation of resources) whether innovation is stimulated predominantly from suppliers or buyers and whether these relationships enhance product and process innovation to different degrees.

2.2.3. Support for a curvilinear relationship

Within studies of social embeddedness, while a positive relationship between actors may initially ensue, further co-operation is not necessarily matched by increases in performance; it may exhibit diminishing and even negative returns (Granovetter, 1973). For instance, Uzzi (1997) found several negative effects of over-embeddedness : over-socialisation, 'feelings of obligation' and managers exhibiting 'negative emotions of spite and revenge' (*ibid,* p59). Similarly Edelman et al. (2004) found strong ties that bind sub-organisational level groups can also act as barriers to new knowledge and ideas at the organisational level, while Boschma

(2005) identified five types of proximity and in each, suggested too little or too much proximity could be problematic for innovation. In fact, many studies report a 'dark' side to both upstream and downstream embedded relationships (Hagedoorn & Frankort, 2008; Villena et al., 2011). Among these, Molina-Morales and Martinez-Fernandez's recent papers on Valencian industrial districts (*ibid* 2009, 2011) are particularly insightful. Using survey data, they found ever higher levels of trust had a negative impact upon innovation among district firms. They suggested this reflected a high reliance upon existing partners which generates complacency, inhibits opportunities for new talent to emerge/participate within operations and reduces experimentation (and consequently, innovation).

2.3 Combining the RBV and the relational-embeddedness perspective.

Cantner and Graf (2011a, p.388) summarise the required combination of differentiated resource bases (RBV) and relational embeddedness (depth) between partners:

> *"In order to draw on creative potential [between cooperating actors]…it is a combination of homophily with respect to trust and mutual understanding on the one hand with some heterogeneity in terms of the respective knowledge stocks and knowledge pieces to be exchanged on the other [that is required]".*

However Cantner and Graf (2011b) note a trade-off must be made between creative potential and trust. As a relationship becomes more embedded, its innovative potential declines because there is less to share which is novel (Cowan et al., 2006). While familiarity and prior accumulated experience teaches a pair of firms how to innovate together, simultaneously it can reduce previously complementary knowledge to duplicative knowledge and to less innovation in the future (Simard & West, 2006). Bonner and Walker (2004) nuanced study on customer involvement with innovation partially supports this proposition; for incrementally innovative projects which build upon an existing knowledge base, they found a strong positive relationship between relational embeddedness with existing lead customers and new product advantage, but there was no such relationship for highly innovative projects with existing lead customers. However, contrary to the suggestions of Bower and Christensen (1995), Bonner and Walker (2004) also found no support for a negative relationship between embeddedness and new product advantage for highly innovative projects either. Finally, Johnsen et al. (2006) suggest that buyer feedback and interaction seemed to be critical at the beginning fluid, stages of new product development and important (although not critical) throughout the remainder of the lifecycle, whereas supplier input was only sought when it was time to bring the product to market especially if supplying tangible components. But if suppliers were supplying intangible knowledge, they may be more important in earlier, more fluid stages of the lifecycle. Thus, the RBV when considered within the context of relational embeddedness within vertical chains may also suggest a potentially curvilinear relationship between the degree of cooperation between firms and innovation.

In summary, we expect that a focal firm's product and process innovation to be positively associated with the depth of co-operative relations with i) buyers and ii) suppliers. However, these relationships maybe tempered by 'over-embeddeness' and beyond a certain point, may become associated with diminishing and even negative returns to innovation. Moreover, the outcomes may differ depending upon whether we are considering upstream or downstream relations in product or process innovations. We stress that we are not necessarily implying direct causality between the depth of supplier-buyer relationships and innovative performance, but merely that the shape of the association between the two variables changes as the relationship depth between the firms increases.

3.0 Research Methodology

3.1 Sample

To obtain a diversified sample of traditional and more modern UK industries, the data was collated from 2,537 firms across aerospace, ceramics, information technology and software, textiles and healthcare (the manufacture of medical equipment and instruments). The sample was drawn using a random stratified sampling process from the membership directories of the respective main industry trade associations. Background information on member firms operating at the 4 digit Standard Industrial Classification (SIC) level enabled the identification of the Managing Director of each firm to whom a postal questionnaire of survey was issued in September 2008. Reminder letters were sent out three and five weeks later.

455 responses were received (17.9% response rate), with 445 (17.5%) providing complete information for the current study[1].The sampling error was 4.6% - acceptable at the 95% confidence interval, (Oerlemans et al., 2006). Tests for non-response bias comparing the mean responses of the early and late respondents, with ANOVA analysis revealed no significant differences (Armstrong & Overton, 1977, see Appendix A1). The sample's representativeness of UK manufacturing was analysed by comparing the distribution of the employment sized bands of the 445 respondent firms with the UK Office of National Statistics (UKONS, 2008) data on the proportion of UK VAT registered units by employment size. There is a slight (but unproblematic - see Freel and Harrison (2006, p.293) skew in the sample away from capturing the smallest firms (1-49 employees) (Appendix A) .

[1] This response rate might be considered low, but because we do not seek some inference of the results to the performance of UK firms in general, but instead seek to capture the variation in key constructs under investigation, the response rate is sufficient for our purposes.

3.2 Questionnaire and Variable Construction

We asked about firms' business background, size, R&D and innovation activities. Crucially, we asked about the strength of the firms' co-operative ties with their *main* buyers and suppliers, i.e. with well-established partners. Following the practice of previous studies, questions related to the previous three years of business trading (i.e. 2005/06-2007/08). The questions on innovation and co-operation covered a range of activities and, where applicable, utilised 5 point Likert scales ensuring the data was both multi-dimensional and multi-scalar. This is a methodological contribution compared to similar studies where categorical variables were employed e.g.De Propris (2002); Freel and Harrison (2006). The primary variables of interest are described below (see details of the survey questions in Appendix B).

Product and Process Innovation: Following (Molina-Morales & Martinez-Fernandez, 2006; 2009); Tsai and Ghoshal (1998) and Tomlinson (2010), respondents were asked to report the number of new product and process innovations[2] the firm had introduced over various activities during the previous three years. It seeks to capture the widest sphere of innovative activity within firms, which may/may not be directly observed through other recognised measures of innovation such as patents.

Buyer Co-operation (over product and process innovation): Firms were asked questions relating to the strength of their co-operative ties with their main clients over a range of activities, based upon Likert scale based items following (Schmitz, 1999; 2000) Knorringa (1999) and Nadvi (1999). Buyer co-operation was constructed in relation to first product and then process innovation using the mean score across the items listed in Appendix B.

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[2] Our measure of innovation closely adheres to the Oslo Manual OECD. (2005) Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data. Paris: Organisation for Economic Co-operation and Development. p.46.

Supplier Co-operation (over product and process innovation): The strength of upstream co-operative ties, was also based upon Schmitz (1999) Knorringa (1999) and Nadvi (1999). Supplier co-operation was constructed in relation to first product and then process innovation using the mean score across the items listed in Appendix B.

Control Variables: To account for the differential impact of firms' internal resources upon the innovation process (Symeonidas, 1996) we included Sales Revenue Growth, Firm Size and Research and Development (R&D) expenditure, which were expected to have a positive impact upon innovation (Cohen & Levinthal, 1990). Their operationalization follows De Propris (2002). Finally, we control for industry differences using dummy variables, with the medical equipment sector being designated as the base.

3.3 Operationalization of variables and data validation

Table 1 provides details of descriptive statistics and Pearson's correlation between the variables. There is some significant bivariate correlation between the co-operation variables. However, given that where firms are embedded in more co-operative relations, they tend to be so in both their upstream and downstream operations, this was expected. The co-operation variables are also significantly correlated with both product and process innovation. Cronbach's alpha (α) for *convergent validity* is reported in Table 1 (col 4). In all cases, it exceeded the accepted minimum of 0.7 satisfying the criteria for internal consistency and reliability (Hair et al., 2007). To test for *discriminant validity*, the variance-extracted estimates for pairs of constructs were compared with the square of their respective correlation coefficient (Hair et al., 2007). These confirmed that each construct was distinct (Campbell & Fiske, 1959). *Face validity* was satisfied by utilising previously used multi-scale items, as discussed above.

Despite following well-established methodological precedents in this type of work, survey data may suffer from a reliance upon managerial retrospective recall (March & Sutton, 1997; Rong & Wilkinson, 2011) and sense-making (Weick, 2000). In our study, this may mean reported innovative outcomes are potentially related to the strength of the key relationship via ex-post managerial sense-making as opposed to necessarily being truly reflective of the depth of a relationship on innovative activity. To militate against this, Rong and Wilkinson (2011) suggest testing for the *validity* of *subjective assessments* of single responses to the survey questions (and thus ensure inter-rater reliability). This was verified by gathering similar independent data on the key variables from a random selected sample of 50 second participants (senior managers) from the surveyed firms (Krackhardt, 1996; Marsden, 1993). These responses were gathered by telephone and this additional control was run for the innovation and co-operation variables, with possible second response bias being tested by a comparison of means; there were no significant differences and the validity of subjective assessments was acceptable. Nevertheless, given the possibility of managerial sense-making, we should interpret our findings cautiously.

Finally and relatedly, to reduce the possibility of common methods bias, we also reversed several items in the survey, while also placing questions on innovation and co-operation in separate sections of the survey to negate the possibility of respondents linking the two categories (see Podsakoff et al., 2003). Anonymity of respondents was also assured to respondents to elicit truthful responses. Finally, a Harman single-factor test was conducted in which all measures were loaded into an exploratory factor analysis where the largest factor accounted for 26.20% of the variance. In short, it is unlikely that common methods bias is a problem in our data (Podsakoff et al., 2003; Sharma et al., 2009).

INSERT TABLE (1) HERE

4. Model Specification, Results and Discussion

4.1 Model Specification

Our model follows previous approaches (e.g. Geroski, 1990; Molina-Morales & Martinez-Fernandez, 2006; 2009; Molina-Morales et al., 2011; Tomlinson, 2010, Tomlinson and Jackson, 2013), and is based upon a standard knowledge production function (namely internal variables), supplemented with independent predictors i.e. the buyer and supplier co-operation variables. To capture the effects of greater depth in co-operative ties upon innovation, we also included quadratic transformations of both buyer and supplier co-operation (Laursen & Salter, 2006; Love et al., 2014; Molina-Morales & Martinez-Fernandez, 2009). The estimating equations are:

Product Innovation = β_0 + β_1 Firm Size + β_2 R&D + β_3 Sales Revenue Growth + β_4 Industry Dummy + β_5 Buyer Co-operation (over product innovation) + β_6 (Buyer Co-operation)^2 + β_7 Supplier Co-operation (over product innovation) + β_8 (Supplier Co-operation)^2 + ε_i (1).

Process Innovation = β_0 + β_1 Firm Size + β_2 R&D + β_3 Sales Revenue Growth + β_4 Industry Dummy + β_5 Buyer Co-operation (over process innovation) + β_6 (Buyer Co-operation)^2 + β_7 Supplier Co-operation (over process innovation) + β_8 (Supplier Co-operation)^2 + ε_i (2).

Estimation of Equations (1) and (2) took the form of a non-linear, inverted U-shaped, (quadratic) regression with the dependent variable being first regressed on the control variables and then the model being supplemented with the predictor (co-operation) variables.

At this point we add the caveat that our estimated models imply causation running from co-operation to innovation. It is also probable highly innovative focal firms actively develop their relationships with established partners further because they have additional resources do so (via increased returns from innovation). In fact, Roper, et al.(2008) emphasise a recursive process, with positive complementarities existing between (collaborative) external sources and both product and process innovations. While we argue our models are theoretically well grounded, and in the absence of longitudinal survey data to explore dynamic feedback loops, we acknowledge the possibility of alternative causation-correlations within our data (see Henley et al., 2006). In interpreting our results, we thus proceed with a degree of caution[3].

4.2 Results

INSERT TABLES (2) and (3) HERE

Both models for product and process innovation are well specified (see Tables (2) and (3)). The R-squared statistics are reasonable and in line with the aforementioned multivariate studies

[3] In fact, Henley et.al (2006) note alternative models are rarely acknowledged in cross-sectional, survey based studies. Following Henley et.al (2006, 527-529)'s suggestions, we ran several supplementary regressions in which both buyer and supplier co-operation acted as dependent variables and both product and process innovation acted as independent regressors. In just 2 cases, product innovation and then process innovation had a marginally significant impact upon supplier co-operation (at the 10% level of significance). Neither regressor had a significant impact upon buyer co-operation. Similarly, we could not use the R-squared statistic to compare which model is the most appropriate as this statistic provide insufficient evidence of causal direction since much depends on the relative variance in dependent and independent variables. While our checks on causality are not completely conclusive, we feel confident our own models can justified on a-priori theoretical grounds.

of open innovation. In each model, they also improve with the addition of the predictor variables. The estimated *Beta* values indicate the magnitude and relative importance of the explanatory variables with the results allowing a degree of comparison with previous research particularly those studies which use categorical measures of co-operation and innovation (see Section 2)[4]. Across both models, the internal resource variables perform well and as expected, the exception being a counter-intuitive insignificant *Beta* coefficient on R&D in the product innovation model (Table 3). This may be due to the use of a frequency based measure of product innovation, which does not differentiate between radical and incremental product innovation and thus R&D may be unable to explain variation in firms' innovation strategies (Griliches, 1990). The measure of process innovation, however, contains an inherent element of value added in process and organisational changes, especially if they enhance firm efficiency; hence the highly positive and significant Beta co-efficient for R&D expenditure in Table (4). The significance of the industry dummy variables reflects the differences in recorded industry innovation levels relative to the medical equipment sector.

A summary of the outcomes is presented in Table 4.

INSERT TABLE (4) HERE

5.0 Discussion

5.1 Product Innovation

Unlike Christensen & Bower (1996) product innovation through closer relations with existing customers do not necessarily lead to 'closed ideas'. Instead the positive (and significant) coefficients on both the linear and quadratic buyer co-operation variables (Table 2, Col 4)

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[4] The use of perceptional scale-based measures does raise some methodological issues, particularly in relation to the interpretation of the *Beta* co-efficients in regression models. However, such data is commonly used in research of this kind and has precedent in the innovation literature (e.g. Molina-Morales & Martinez-Fernandez, 2006, 2009, 2011; Tomlinson, 2010). This suggests the use of such measures is valid and the results in the paper are thus robust (Hair et.al, 2007).

support the findings of Franke and Piller (2004) Greer and Lei, (2012) and Zander and Zander (2005). Greer and Lei (2012) suggest collaborative innovation with customers can speed up the process of New Product Development (NPD). Indeed in the buoyant economic period our data covers (2005-8), time based competition would have been critical explaining the positive relationship found.

Our results might also reflect hidden characteristics in the data itself. Given our inclusion of ceramics and textile industries (which constitute 47% of respondent focal firms) there may be a predominance of wholesalers among the respondents' self-identified 'main buyers'. Wholesalers may draw feedback from a wide range of their own downstream markets and act as a conduit, assimilator and filter for that knowledge, which is then fed to the manufacturer to enhance innovation upstream. Effectively, a relationship with a wholesaler as the main buyer may actually reflect the focal firm's indirect relationship with many customers as the original sources of external knowledge, whereas in aerospace and healthcare, one might expect a more direct and singular relationship between the focal firm and its main buyer. Prior studies have suggested a positive relation existing between the number of indirect ties and innovation (e.g. Ahuja, 2000; Salman & Saives, 2005) but unfortunately our data does not allow us to confirm this.

In contrast, supplier co-operation is positively associated with product innovation but only to a certain point. The negative (albeit marginal) coefficient on the quadratic term (for supplier co-operation) suggests there maybe optimal depth in tie strength with suppliers (Table 2, Column 4). This supports Lakshman and Parente (2008) and Cousins et al. (2011), and adds detail to Hagedoorn and Frankort (2008), Rossetti and Choi (2005), Villena et al. (2011) in that a 'gloomy side' to deep relationships with suppliers for generating product innovations may exist. Our sample suggests established suppliers may be involved in product innovation very early on in the design and prototype stages (Cusumano & Takeishi, 1991) which could be a major source of competitive advantage, particularly if supplying intangible knowledge ((Johnsen et al., 2006). It may also reflect upstream suppliers 'locking in' downstream clients to existing technologies, which can lead to problems associated with over-embeddedness. In short, the managerial implication of our analysis of the supplier - focal-firm – buyer chain, is focal firms should devote greater resources to developing their relationships with buyers relative to those with suppliers, if they wish to continue to develop new products.

5.2 Process Innovation

With regards to buyer co-operation, a positive linear association exists in a focal firm's relationship with main buyers and its' rate of process innovation (Table 3, Col 2). It is possible that collaboration with buyers on product innovation extends to process innovation. For instance, collaboration with buyers over new product designs and specifications might also lead to greater collaboration in processes such as marketing/distribution (Athaide et al., 1996) or production techniques (Kraft, 1990) to improve the overall desirability and efficiency of the final product. There is also a positive (albeit linear) relationship existing between the focal firm and its main suppliers over process innovation. Again, the preceding arguments generally apply, and in addition it appears that the focal firms, in our sample at least, are not inhibited by concerns about opportunism upstream (Noordhoff et al., 2011; Torugsa & Arundel, 2013).

We should note the introduction of supplier co-operation appears to render the buyer co-operation variables insignificant in the later regressions indicating a potential collinearity issue (Table 3, Columns 3 and 4)[5].

In answer to our second research question, firms which are weaker product innovators may be over investing in relationships with their main suppliers. The managerial implication

[5] Collinearity between buyer and supplier co-operation (over process innovation) is partly a consequence of the survey data trying to capture both the depth and breadth of co-operation along the supply chain. Potential solutions (in estimation) would be reduce the number of items included in each construct, or to combine both constructs into one to capture overall vertical collaboration. However, both methods involve the loss of information and are not followed here.

is that given investment into deep relationships with main buyers is positively correlated with both greater product innovation and also process innovation then - in the face of limited resources - a greater proportion of these should be devoted to deepening key buyer relationships over key supplier relationships.

6.0 Research Contribution

Our paper makes several contributions. First, by exclusively studying the *depth* of supply chain relationships and their impact upon innovation we add balance to the literature which has predominantly concentrated on the breadth of external relationships. Second, our use of Likert scales provides a detailed, variable measure of the strength of co-operation in innovation. Finally, our focus on upon both buyer and supplier *dyads* demonstrates the influence of up- and downstream relationships in terms of their *differential impact* on the focal-firm's innovation in products and processes, whereas previous studies have focussed predominantly on innovation in a more general sense, or exclusively upon new product development. All this deepens our understanding of this phenomenon and demonstrates its multifaceted nature which leads to complicated decision making requirements by managers and the policymakers and intermediaries who seeks to encourage and establish inter-firm relationships.

6.1 Limitations and Further thoughts

In additional to the aforementioned methodological limitation in terms of reliance on managerial recall, a further shortcoming of our data is that we are unable to match a specific supplier relationship to specific buyer relationship within a firm on a 1-2-1 basis to provide a sense of the "true" supply chain for a particular product/ project. We also do not know what occurs within the focal firm to co-ordinate the pressures from both the up- and down-stream directions and combine them usefully into new products/ processes i.e. we do not investigate the role of the focal firm as a structural bridge (Burt, 1992). In-depth qualitative studies or case studies (e.g. Coviello & Joseph, 2012), or more processual based approaches (e.g. Garud et al, 2013) or analytical sociology (see Hedström & Bearman, 2009) might usefully be employed to examine such issues in detail.

Our study only focussed on established relationships with suppliers and buyers over a three year period. There is a possibility that the absence of inverse-U relationships in three of our four hypotheses, is due to this period being too short to pick up the turning point. Given the period 2005-08 was generally buoyant for the UK economy, it may also be the case that our data window captures a stage where the relationship with customers is moving from one of initial exploration (implying slow innovation) to one of exploitation (implying accelerating innovation). Future work extending the period of study may lead to different insights. Indeed Love et al. (2014) have called for longer timeframes in open innovation studies. This might also address some of the issues relating to capturing the feedback loops mentioned in Section (4). We also recognise the range of industries in our dataset is diverse and that an industry level analysis of the issues might yield different results across these. However, attempts to generate industry specific analyses proved problematic due to issues of multi-collinearity arising in analysing quadratic functions with the smaller (industry) sub-samples.

To conclude, the simultaneous but contrasting patterns of supplier relationships and customer relationships on product innovation and process innovation suggests that the focal firm has some very complex strategic decision making to do with respect to the allocation of resources to develop these relationships. Without adequate capability development in this domain, the focal firm could potentially over- or under- invest in relationship-deepening in the wrong direction.

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Table (1) Descriptive Statistics and Bivariate correlations (to two decimal places)

N=445	Mean	S.D	α	VIF	1	2	3	4	5	6	7	8	9
1. Product Innovation	3.47	1.60	0.79	N/A	1								
2. Process Innovation	2.59	1.15	0.78	N/A	0.52***	1							
3. Firm Size	2.6	1.71	N/A	N/A	0.28***	0.37***	1						
4. R&D expenditure	2.03	1.25	N/A	1.52	-0.05	0.03	-0.10**	1					
5. Sales Growth	0.59	0.49	N/A	1.19	0.11**	0.21***	0.20***	0.06	1				
6. Co-operation with Buyers (product innovation)	3.32	0.86	0.76	1.27	0.17***	0.26***	0.19***	0.09	0.04	1			
7.Co-operation with Buyer (process innovation)	2.54	0.75	0.72	1.36	0.11**	0.22***	0.12**	0.13***	-0.01	0.65***	1		
8. Co-operation with Suppliers (product innovation)	2.94	0.99	0.75	1.28	0.19***	0.31***	0.24***	0.01	0.01	0.42***	0.46***	1	
9. Co-operation with Suppliers (process innovation)	2.39	0.85	0.87	0.85	0.18***	0.32***	0.26***	-0.01	0.03	0.48***	0.53***	0.83***	1

*** Pearson's Correlation is significant at the 0.01 level (2-tailed test)
** Pearson's Correlation is significant at the 0.05 level (2-tailed test)
* Pearson's Correlation is significant at the 0.10 level (2-tailed test)
α – Cronbach's alpha
VIF – Variance Inflation Factor

Table (2) Multivariate Regression Analysis (Dependent Variable: Product Innovation)

Product Innovation

Variable	(1)	(2)	(3)	(6)
Constant	-1.371*** (0.201)	-1.267*** (0.203)	-1.260*** (0.203)	-1.273*** (0.204)
Firm Size	0.204*** (0.028)	0.192*** (0.028)	0.182*** (0.028)	0.181*** (0.028)
R&D expenditure	0.046 (0.038)	0.033 (0.038)	0.030 (0.038)	0.021 (0.039)
Sales Growth	0.226** (0.093)	0.231** (0.092)	0.238** (0.092)	0.225*** (0.093)
Textiles	0.920*** (0.170)	0.843*** (0.171)	0.839*** (0.171)	0.814*** (0.171)
Ceramics	0.915*** (0.167)	0.895*** (0.166)	0.921*** (0.166)	0.903*** (0.166)
Aerospace	0.422** (0.163)	0.365** (0.164)	0.379** (0.164)	0.372** (0.164)
Information Technology & Software	0.403** (0.171)	0.331* (0.173)	0.401** (0.176)	0.393** (0.176)
Co-operation with Buyers		0.118** (0.046)	0.080* (0.048)	0.102** (0.052)
Co-operation with Buyers^2				0.044* (0.026)
Co-operation with Suppliers			0.095** (0.05)	0.102** (0.051)
Co-operation with Suppliers^2				-0.011* (0.006)
Adjusted R^2	0.157	0.168	0.173	0.194
F statistic	12.843***	12.216***	11.323***	9.494***
N = 445				

*** p<0.01; ** p<0.05; * p < 0.10, Non-standardized regression coefficients (errors in brackets)

Table (3) Multivariate Regression Analysis (Dependent Variable: Process Innovation)

Process Innovation

Variable	(1)	(2)	(3)	(4)
Constant	-1.398*** (0.196)	-1.289*** (0.196)	-1.277*** (0.192)	-1.305*** (0.193)
Firm Size	0.231*** (0.027)	0.218*** (0.027)	0.197*** (0.027)	0.199*** (0.027)
R&D expenditure	0.114*** (0.037)	0.092** (0.037)	0.100** (0.037)	0.093** (0.037)
Sales Growth	0.321*** (0.091)	0.331*** (0.090)	0.339*** (0.09)	0.328*** (0.088)
Textiles	0.674*** (0.166)	0.604*** (0.165)	0.605*** (0.162)	0.593*** (0.162)
Ceramics	0.516*** (0.163)	0.490*** (0.161)	0.551*** (0.159)	0.531*** (0.159)
Aerospace	0.342** (0.160)	0.310** (0.158)	0.317** (0.155)	0.307** (0.155)
Information Technology & Software	0.034 (0.167)	0.007 (0.166)	0.037 (0.163)	0.042 (0.162)
Co-operation with Buyers		0.162*** (0.048)	0.039 (0.054)	0.024 (0.057)
Co-operation with Buyers^2				0.047 (0.034)
Co-operation with Suppliers			0.220*** (0.050)	0.216*** (0.053)
Co-operation with Suppliers^2				0.016 (0.032)
Adjusted R^2	0.197	0.216	0.247	0.248
F statistic	16.566***	16.294***	17.207***	14.370***
N = 445				

*** p<0.01; ** p<0.05; * p < 0.10, Non-standardized regression coefficients (errors in brackets)

Table (4) Summary results

Relationship	Evidence of (positive) linear relationship	Evidence of curvilinear relationship
Buyer cooperation on product innovation	Yes	No
Buyer cooperation on process innovation	Yes	No
Supplier cooperation on product innovation	Yes	Yes
Supplier cooperation on process innovation	Yes	No

Appendices

Appendix A: Proportion of Firms by Firm Size

Number of employees	All Firms (Manufacturing)	
	Sample	Population
1-49	74.6%	93%
50-249	19.4%	5%
>250	6%	3%

Sources: UK Office for National Statistics (2008).

Note: The UK Office for National Statistics (2008) data measures the proportion of VAT registered units (based upon 2003 SIC codes). As such, it does not specifically account for the ownership of such units. Since firms may own multiple units, the National Statistics data may overstate the proportion of smaller firms in each strata of the actual population.

Appendix B: Variable Construction (survey items used)

Product Innovation i). The number of new product lines introduced ii) The number of changes/improvements to existing product lines

Process Innovation: i). The Number of new equipment/ technology introduced in the production process ii). The number of new input materials introduced in the production process iii). The number of organisational changes/improvements made in the production processes (Based upon Tsai and Ghoshal, 1998; Molina-Morales and Martinez-Fernandez (2006, 2009, 2011.)

Firm Size: Number of employees on farm (Scale 1-5; where 1 = less than 10, 2 = 10-49, 3 = 50-99, 4 = 100-250, 5 = 250-499). (Based upon De Propris, 2002; Freel and Harrison, 2006).

R&D expenditure % of turnover spent on R&D. (Scale 1-5; where 1 = 1-5%, 2 = 6-10%, 3 = 11-20%, 4 = 21-30%, 5 = Greater than 30%). (Based upon De Propris, 2002; Freel and Harrison, 2006).

Sales Revenue Growth 1/0; 1 if firm has attained sales revenue growth over the three year period 2005/06-2007/08; 0 otherwise. (Based upon De Propris, 2002).

Co-operation with Buyers (Product Innovation): i). Improving Product quality ii). New Product designs iii). Exchange of information/experiences

Co-operation with Buyers (Process Innovation): i). Marketing and Distribution of products ii). Production organisation iii). Technological upgrading iv). Exchange of information/experiences

Co-operation with Suppliers (Product Innovation): i). Improving quality of inputs
ii). Exchange of information/experiences

Co-operation with Suppliers (Process Innovation): i). Improving delivery times
ii). Labour training iii). Production organisation iv). Technological upgrading v). Exchange of information/experiences.

(Co-operation Scales, where 1 = no co-operation and 5 = Very high level of co-operation). Based upon Schmitz (1999, 2000), Knorringa (1999) and Nadvi (1999)